# PVDIS at JLab 6 GeV

Kai Pan
Massachusetts Institute of Technology

On Behalf of HAPPEX Collaboration

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# OUTLINE

- Motivation
- JLab Hall A and PVDIS Experiment Setup
- Data Analysis Status
- Summary and Outlook

# Motivation No.1

## Testing Electroweak Standard Model

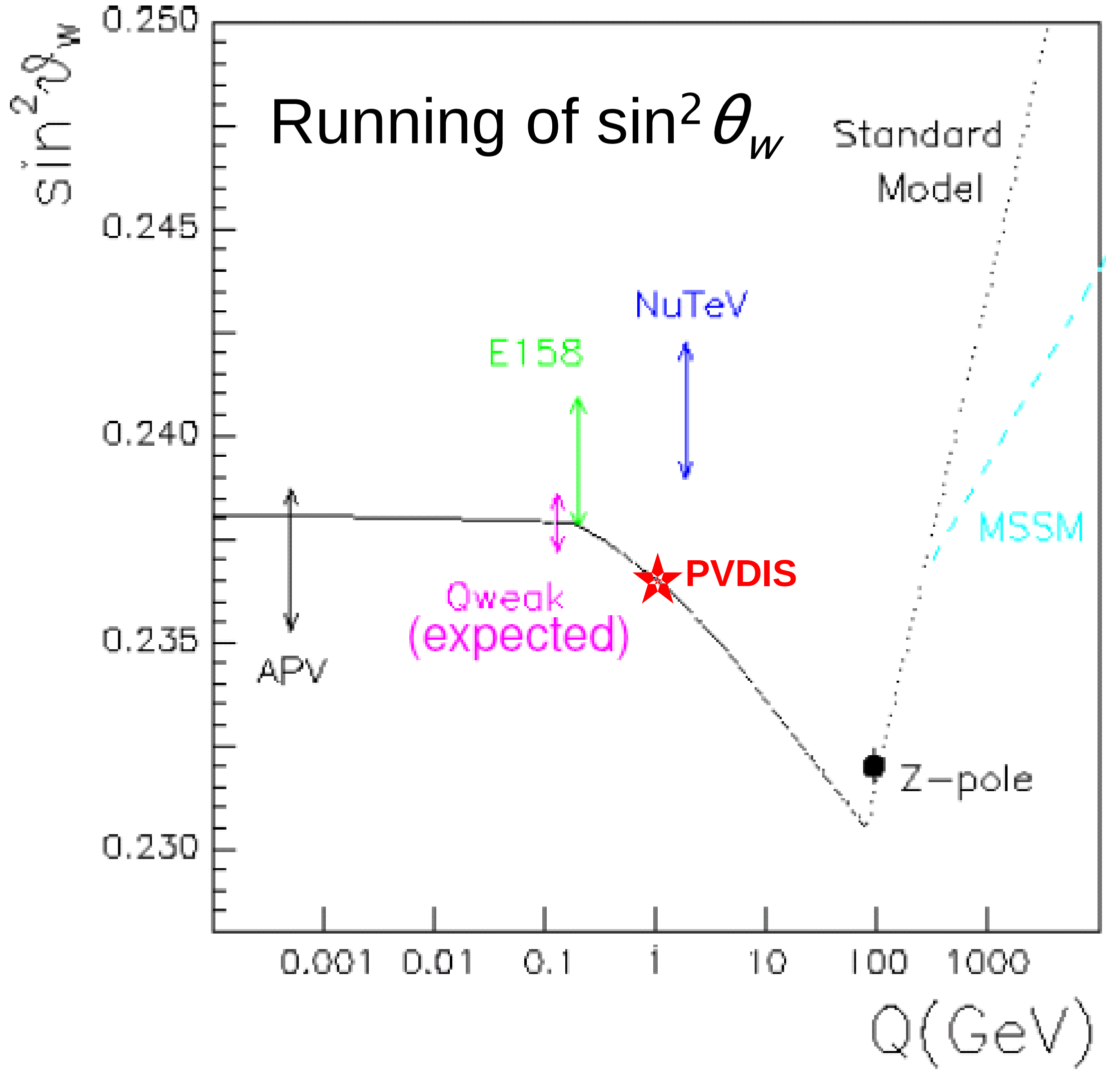
- Standard Model is a successful theory. Data confirms the electroweak sector of the SM at a few 0.1%.

- *Deficiencies* of the Standard Model: mass origin, neutrino oscillation, matter antimatter asymmetry, hierarchy problem.

- People believe SM is only a piece of some larger framework, and try to find *new physics* beyond Standard Model.

Direct Search: LHC, Tevatron, etc… (Higgs mechanism)
Indirect Search: SLAC E158 (Moller), Atomic-PV, Sample, NuTeV, Qweak, PVDIS (Electroweak couplings or weak mixing angle)

## Motivation No.1 <u>Testing Electroweak Standard Model</u>



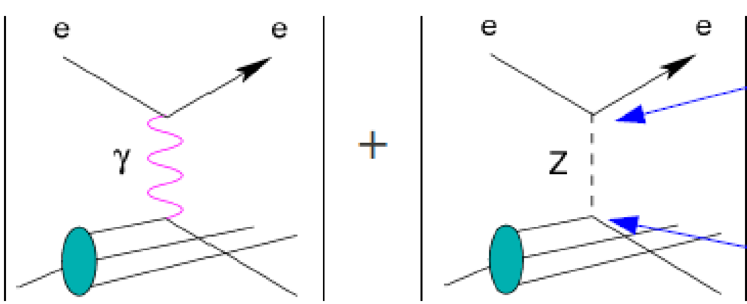

However, PVDIS 6GeV is NOT to measure $\theta_w$,
but the electroweak coupling constant combination.

# Motivation No.2 Constrain the poorly known coupling constant combination ($2C_{2u}$-$C_{2d}$)


(polarized beam, unpolarized target)

$$A = \frac{\sigma\uparrow - \sigma\downarrow}{\sigma\uparrow + \sigma\downarrow}$$

$A_{PV} =$




$$\frac{1}{2}\left(\bar{e}\gamma_\mu(g_V^e - g_A^e\gamma^5)e\right)$$

$$\frac{1}{2}\left(\bar{q}\gamma_\mu(g_V^q - g_A^q\gamma^5)q\right)$$

DIS is a unique probe accessing $C_{2q}$

$$A_d = (540\ ppm)Q^2 \frac{2C_{1u}[1+R_C(x)] - C_{1d}[1+R_S(x)] + Y\boxed{(2C_{2u} - C_{2d})}R_V(x)}{5 + R_S(x) + 4R_C(x)}$$

1ppm=$10^{-6}$

PDF

Measurement so far not as precise as $C_{1q}$

$$C_{1u} = g_A^e g_V^u = -\frac{1}{2} + \frac{4}{3}\sin^2(\theta_W)$$

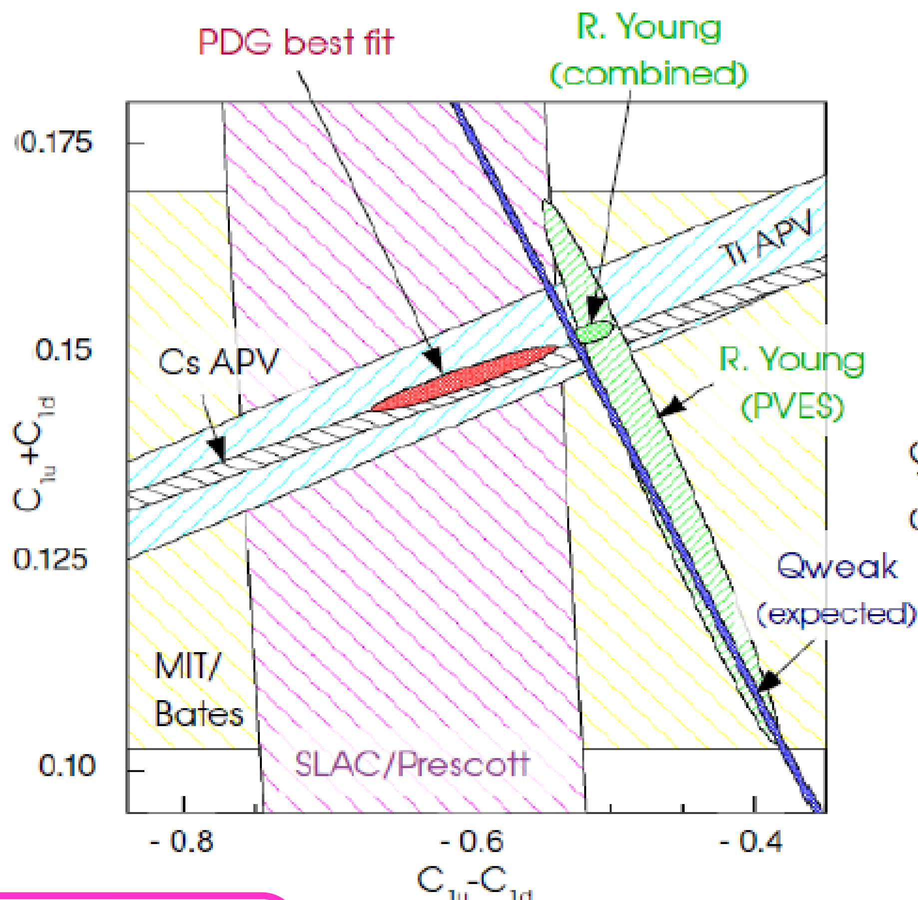
$$C_{1d} = g_A^e g_V^d = \frac{1}{2} - \frac{2}{3}\sin^2(\theta_W)$$

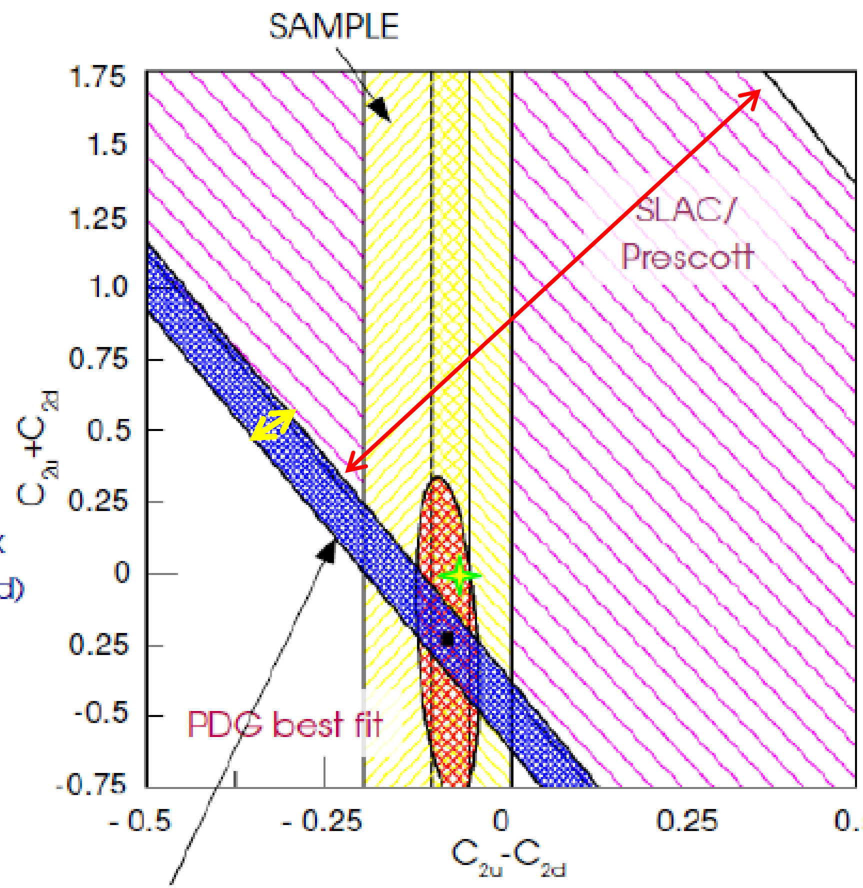
$$C_{2u} = g_V^e g_A^u = -\frac{1}{2} + 2\sin^2(\theta_W)$$

$$C_{2d} = g_V^e g_A^d = \frac{1}{2} - 2\sin^2(\theta_W)$$

# Motivation No.2

## Constrain the poorly known coupling constant combination ($2C_{2u}$-$C_{2d}$)




PDG2002 (best):
$2C_{2u}$-$C_{2d}$ =
-0.08 (+-) 0.24

$\Delta(2C_{2u}$-$C_{2d}) = 0.06$

Expected: JLab 6 GeV PV-DIS E08-011
(assuming small hadronic effects and a
4% stat error on Ad)

# Motivation No.3

## Constrain the hadronic effect

- Non-perturbative QCD (higher-twist) effect
- Charge Symmetry violation (equivalence of u,d quark distribution in proton and neutron)

Provide important guide on the future *PVDIS 12 GeV* upgrade, for which the ultimate goal is to extract electroweak coupling constant as well as $\sin^2(\theta_w)$ from the asymmetry free from hadronic effects.

# Section II: Jlab Hall A and PVDIS Experiment Setup

- JLab: Linear accelerator provides continuous polarized electron beam
  - $E_{beam}$ = 6 GeV
  - $P_{beam}$ = 90%
- 3 experimental halls (Hall A)
- Spokesperson:

  Xiaochao Zheng (UVa)

  Bob Michaels (JLab)

  Paul Reimer (Argonne)

Thesis student:

  Diancheng Wang (UVa)

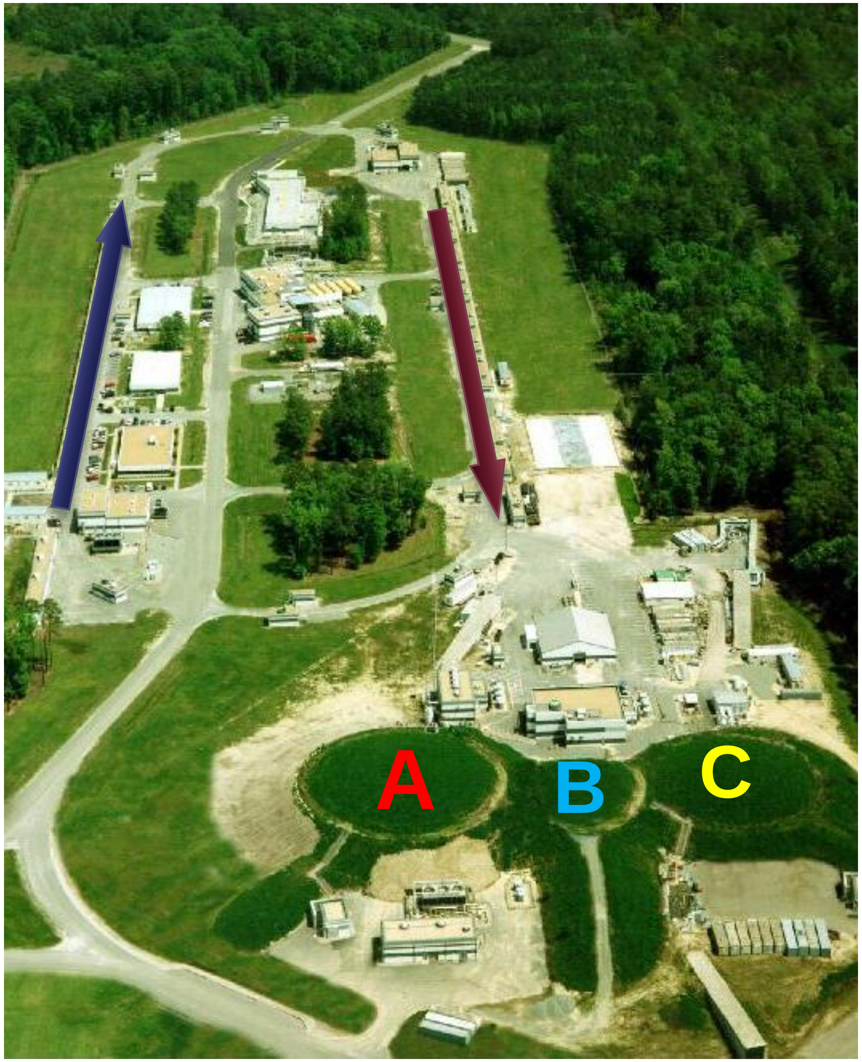
  Xiaoyan Deng (UVa)

  Kai Pan (MIT)

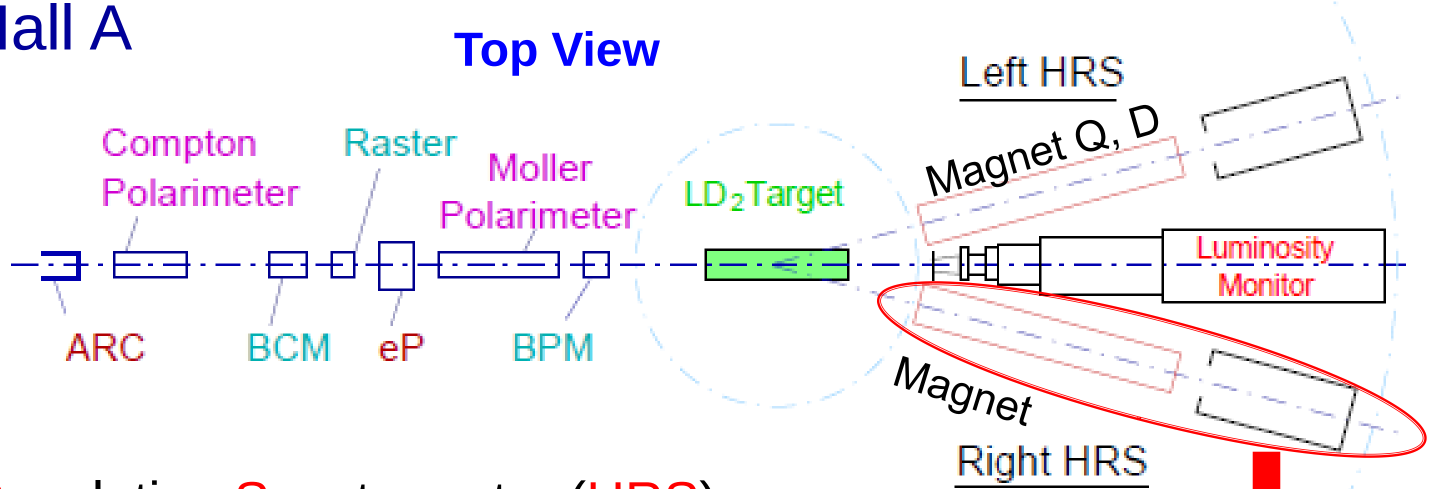
Postdoc:

  Zhiwen Zhao (UVa)

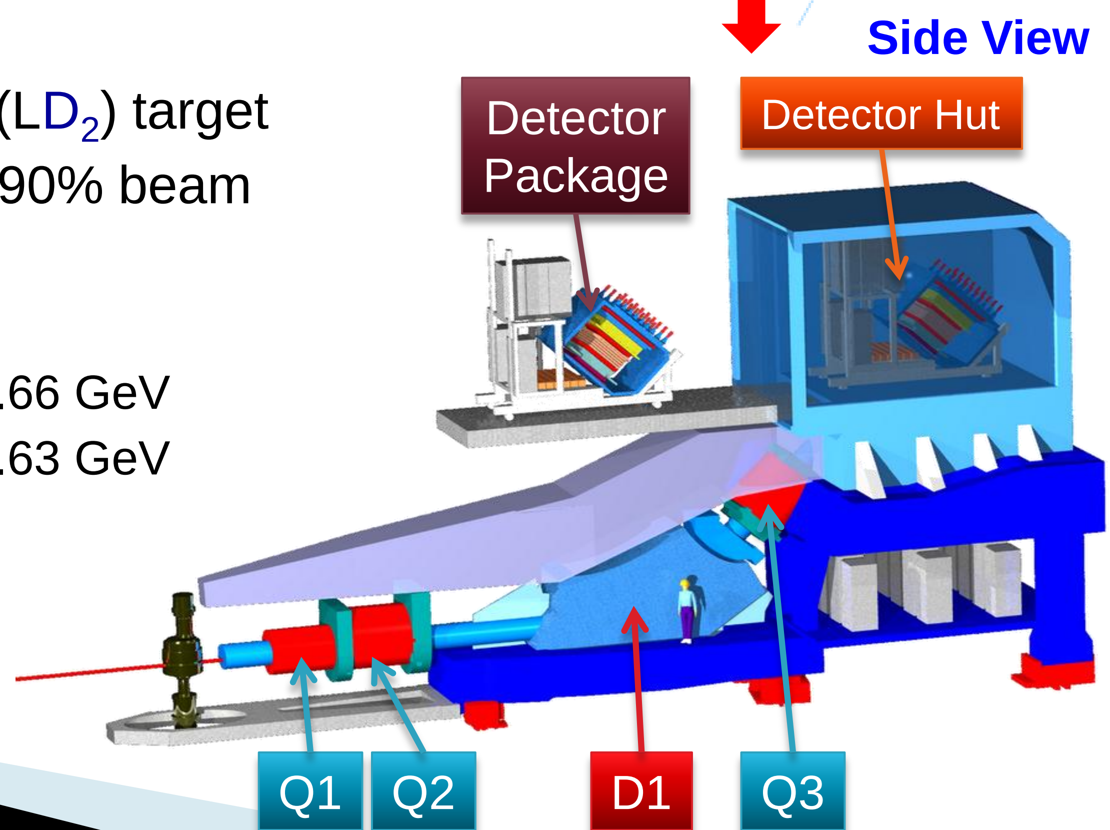
  Ramesh Subedi (UVa, George Wahsington University)



# Jlab Hall A




- High Resolution Spectrometer (HRS)
- Beam Energy 6.067 GeV
- 20 cm long liquid deuterium ($LD_2$) target
- 100 uA polarized beam with 90% beam polarization
- Two kinematics
  - $Q^2$=1.1(GeV)$^2$ ; 12.9$^0$ ; $P_0$ = 3.66 GeV
  - $Q^2$=1.9(GeV)$^2$ ; 20.0$^0$ ; $P_0$ = 2.63 GeV
- X = 0.25 ~ 0.3



# PVDIS Experiment Setup

**Two DAQ System:**

➢ regular High Resolution Spectrometer (HRS) DAQ

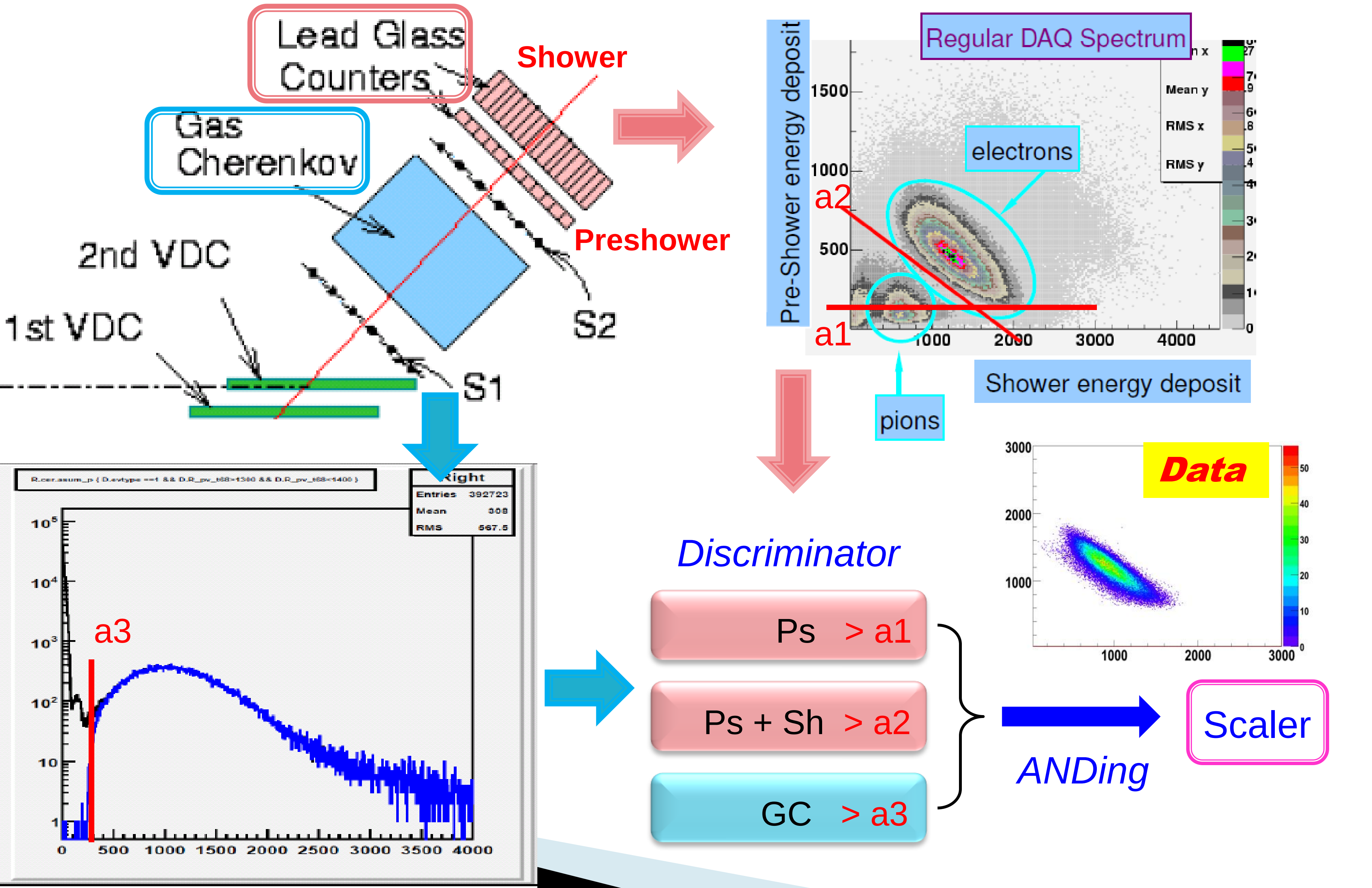
Limitation: Max event taking rate is only 2KHz for each arm, which is far below the statistics requirement in PVDIS.

Opened occasionally at low rate to record full event information for kinematics, efficiencies and Particle Identification (PID) analysis

➢ Parity fast counting DAQ NEW

- Scaler based (fast counting with very low deadtime)
- Measured scaler counting rate is up to 500KHz for each arm
- Hardware-based Particle Identification (PID)

# Parity fast-counting scaler DAQ (Hardware-based PID)



# Section III: Data Analysis Status

*Data Analysis Flow Chart*

**HRS**

1) Track reconstruction
2) Beam polarization
3) Deadtime correction
4) Pion contaminaiton
5) Electron detection efficiency
6) Other correction

**Input** →

Hall A Monte Carlo (HAMC)
Hall A Trigger Simulation (HATS)

→ $A_{sim}$

?

**Parity**

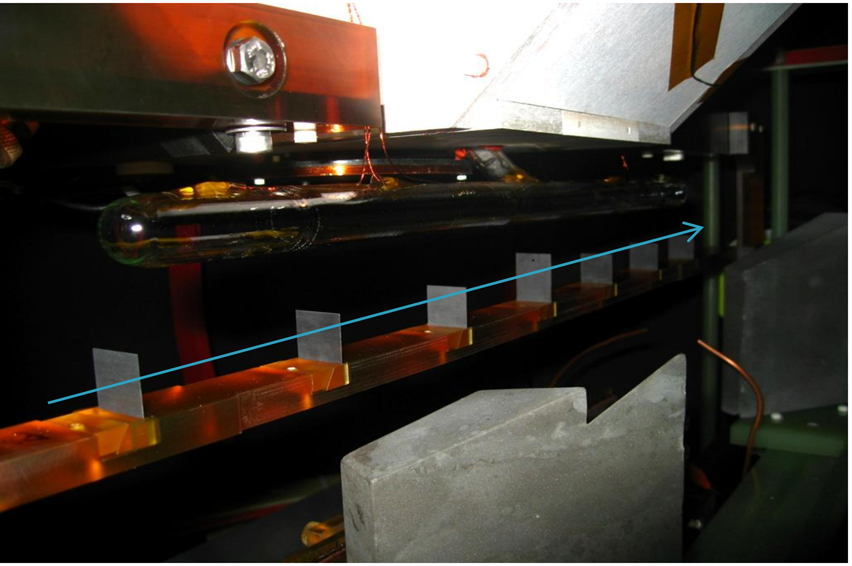
Parity Data:

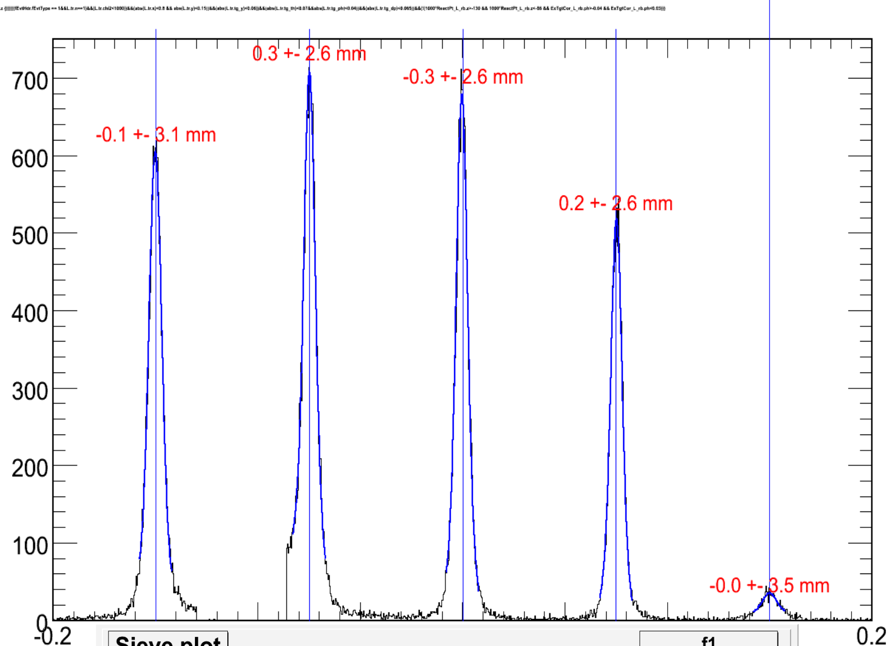
1) Pedestal subtraction
2) Beam linearity calibration
3) Selection of clean cut
4) Charge asymmetry analysis
5) Regression and dithering

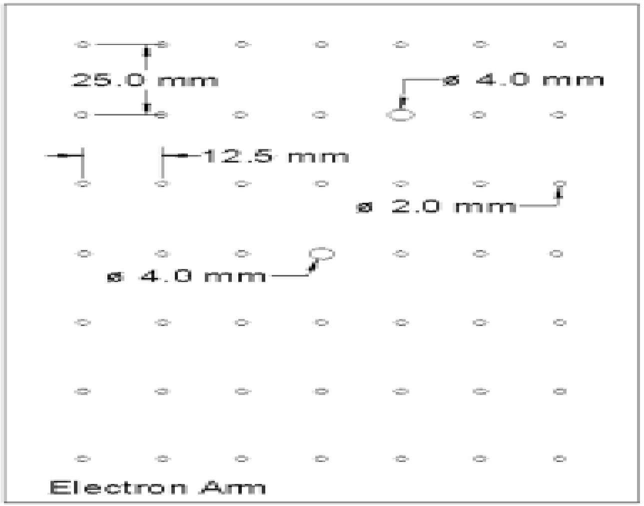
→ $A_{exp}$

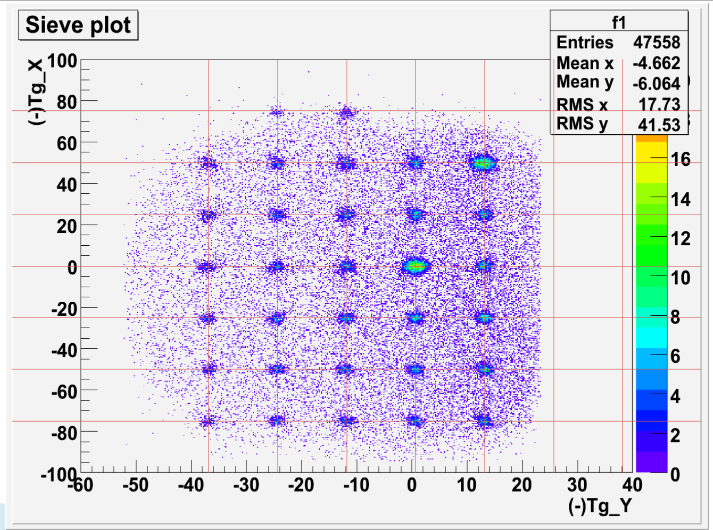
## 1. Tracking reconstruction

- DIS asymmetry is sensitive to Q^2, thus tracking reconstruction
- After calibration, asymmetry uncertainty due to Q^2 reconstruction is <1%



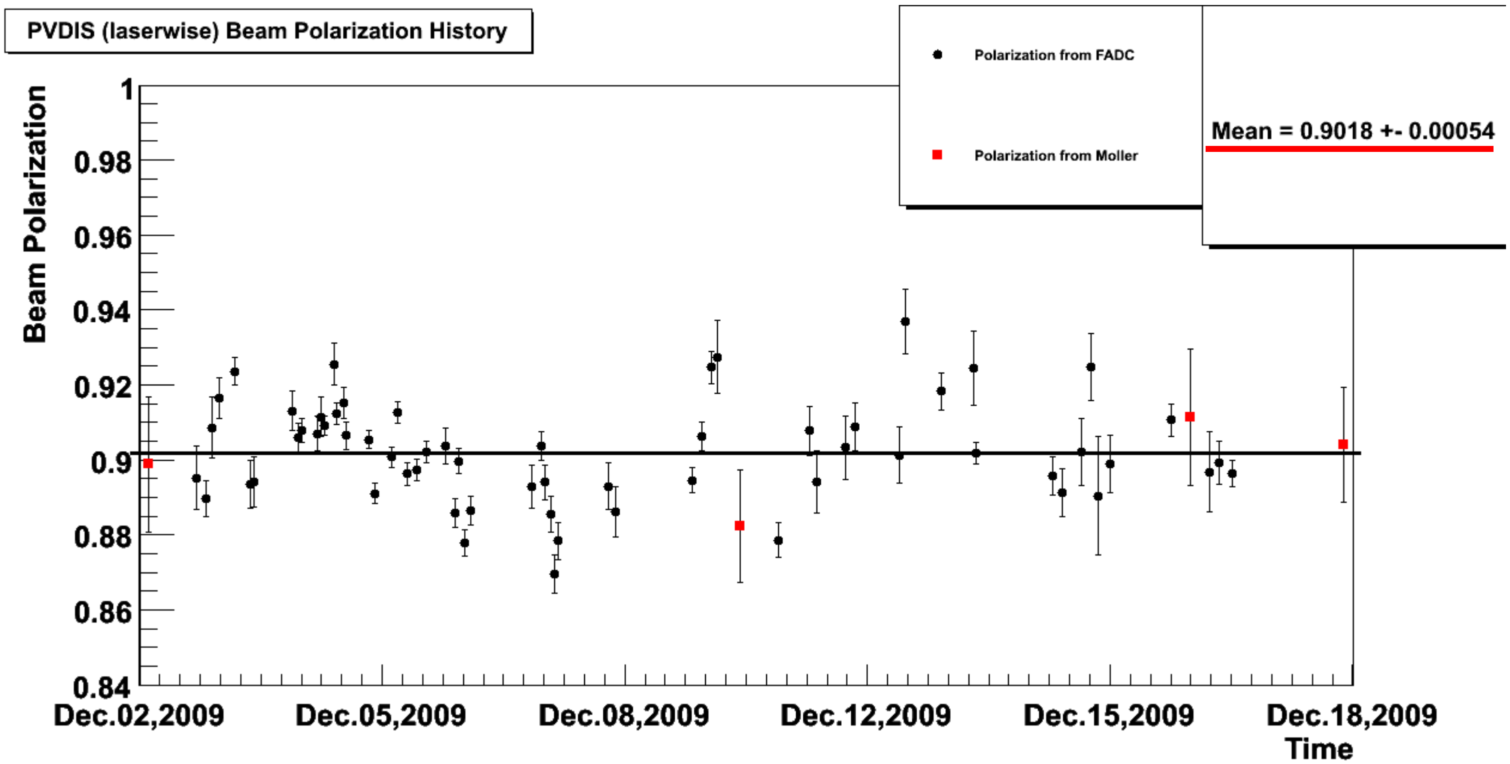


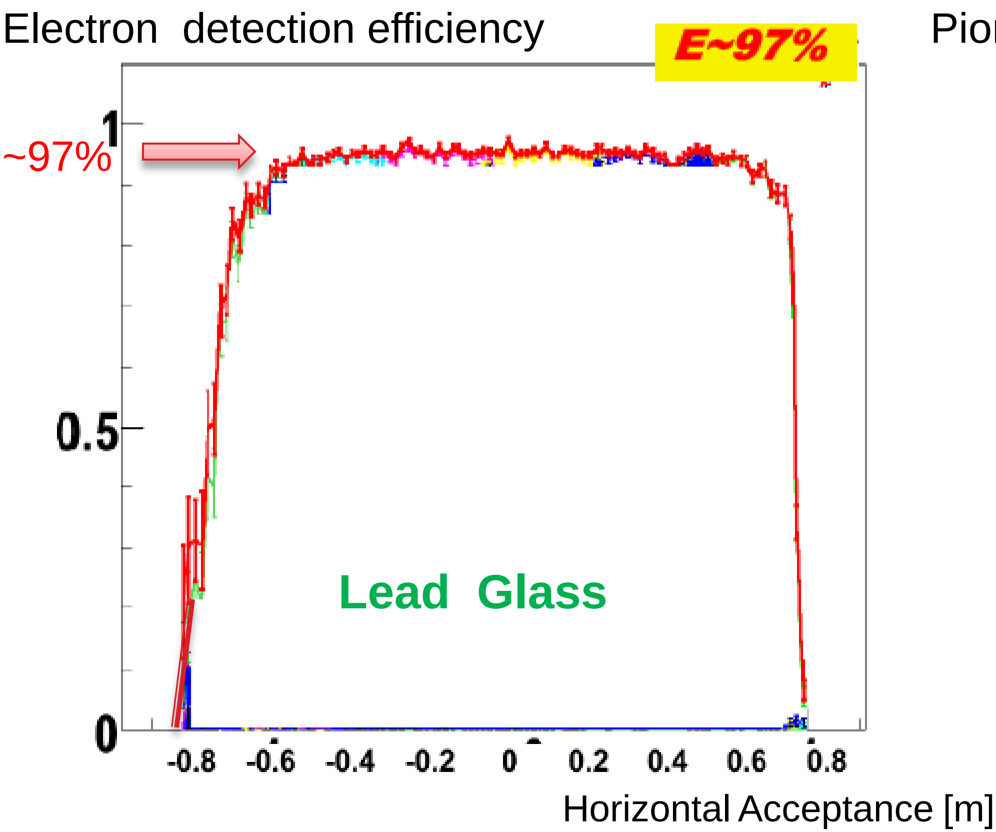



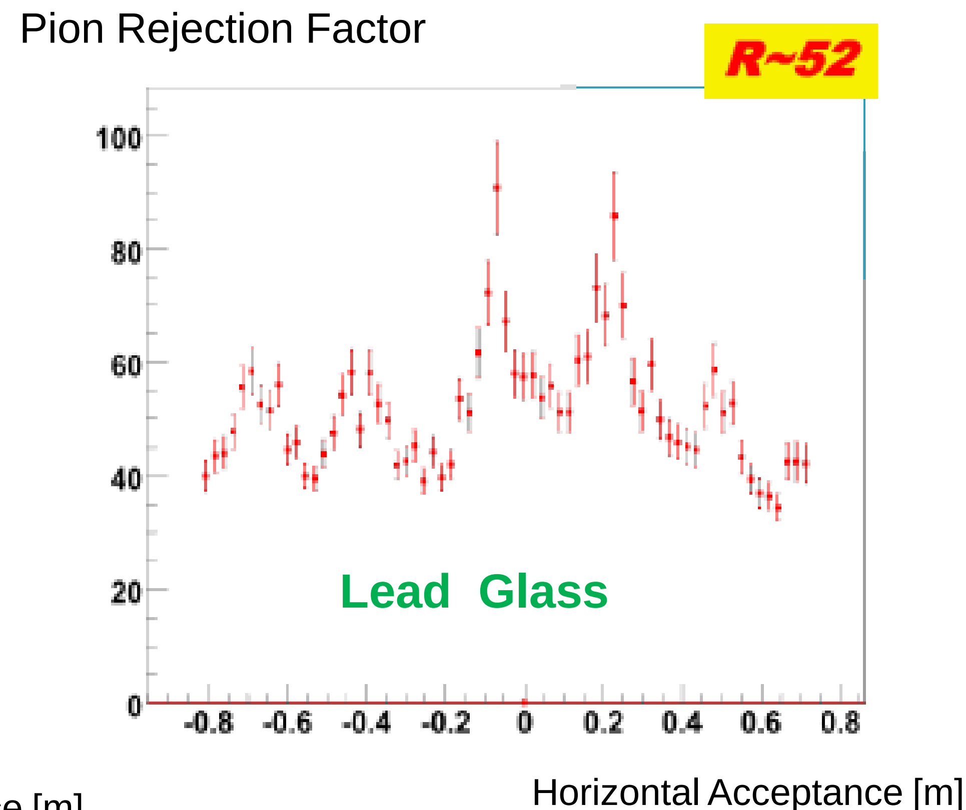
## 2. Beam Polarization

- $A' = A_{measure}$ / Polarization
- Use Compton Polarimeter to measure the beam polarization up to 2% accuracy
- Moller Polarimeter as a cross check (consistent)
- P ~ 90% (+ -) 2%



# 3. Particle Identification Performance

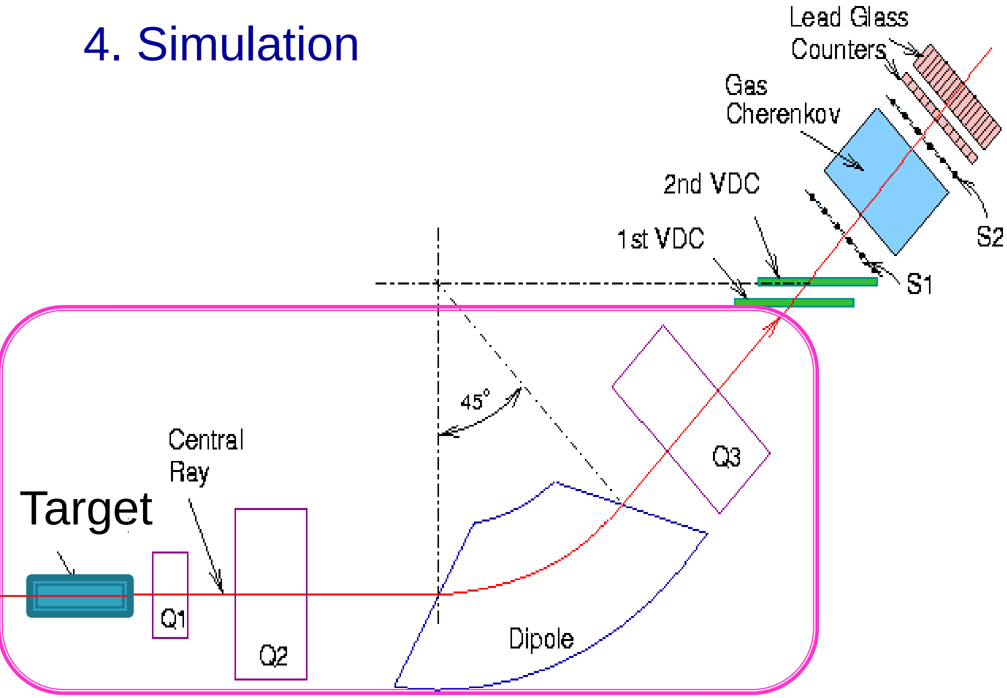



| | Lead glass | Gas Cherenkov | Overall |
|---|---|---|---|
| Electron efficiency | 97% | 96% | 95% |
| Pion Rejection Factor | 52 | 200 | 10e4 |

Asymmetry correction due to **electron efficiency <0.5%**
**pion contamination <0.1%**

# 4. Simulation




Hall A Monte Carlo (HAMC)

**Simulating experiment starting from initial beam to detector package (not included)**

- **Incoming and scattered electron energy loss (ionization and bremsstrahlung)**
- **DIS cross section and asymmetries are calculated by using world data fit (PDF)**
- **Standard Quadrupole and Dipole magnet transportation functions**

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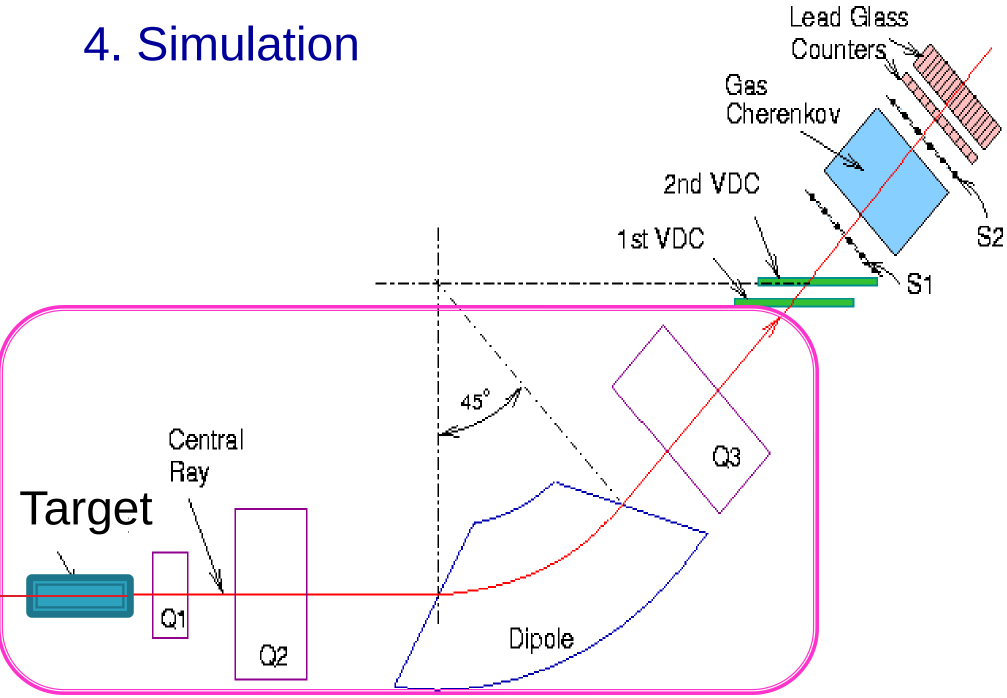


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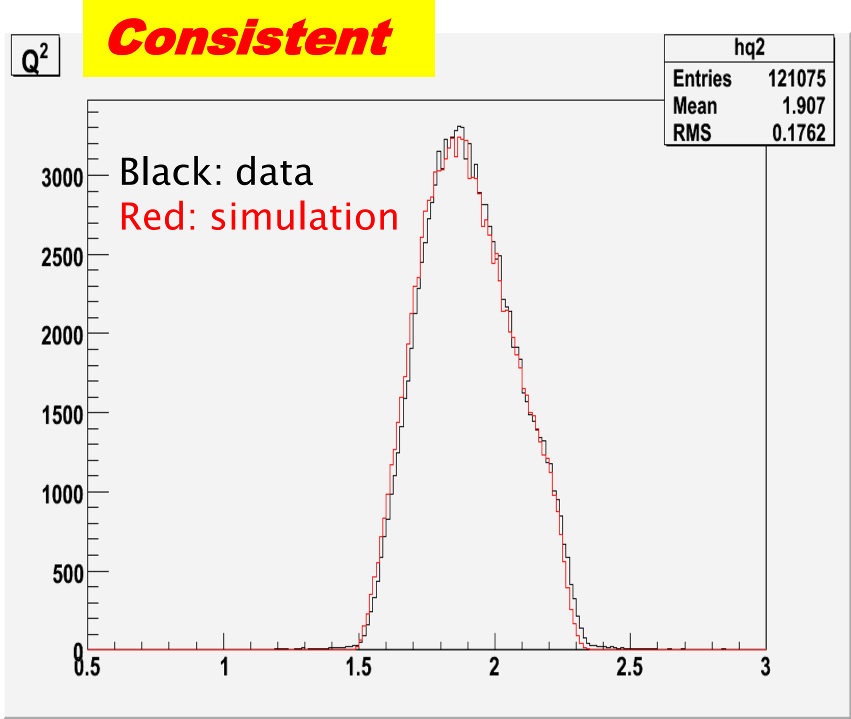

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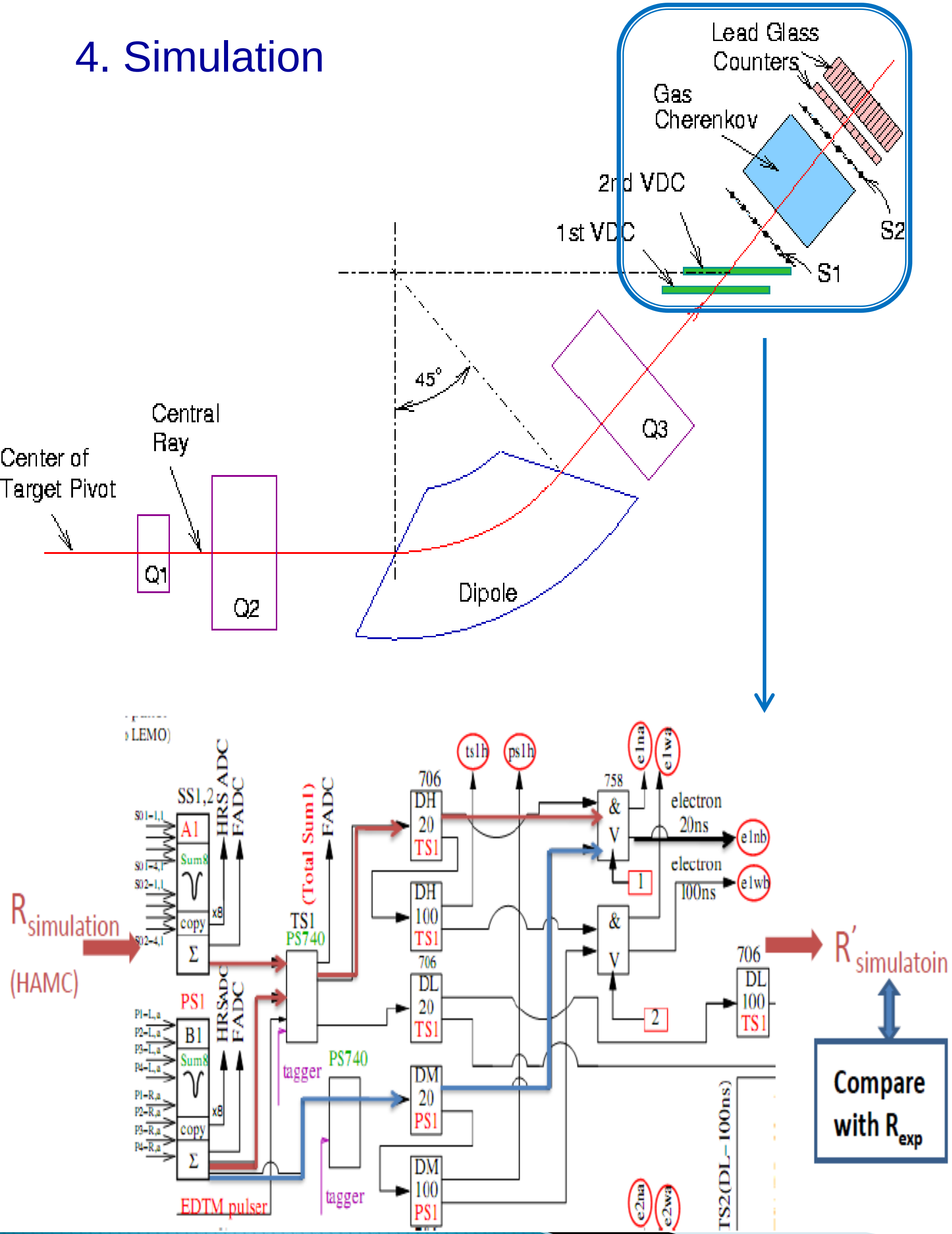

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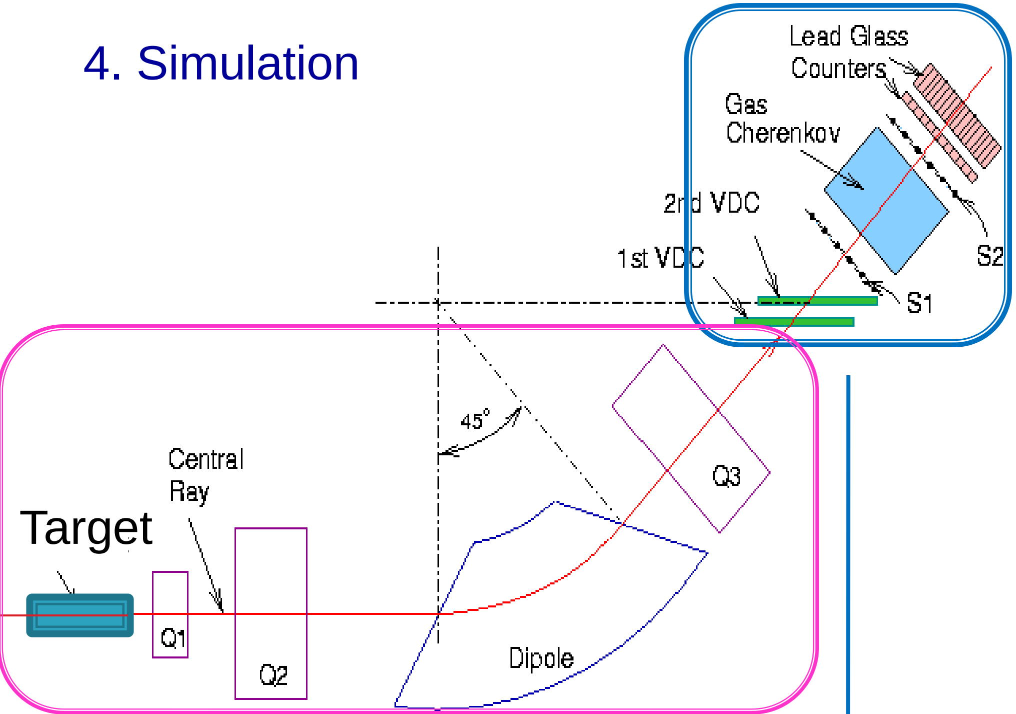



## Hall A Trigger Simulation (HATS)

Credit: Diancheng Wang

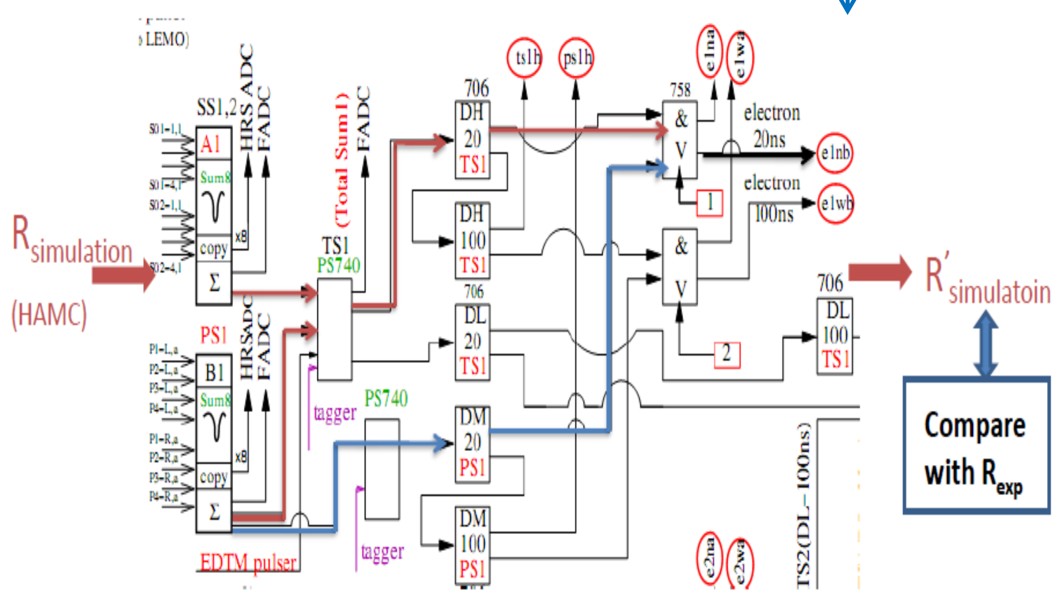
➢ **Simulating detector and DAQ response to the incoming physics events generated by HAMC**

➢**Deadtime Simulation**

$$A' = A_{measure}\ (1\text{-Deadtime})$$

➢ **Deadtime data is well understood. (consistent with the simulation)**

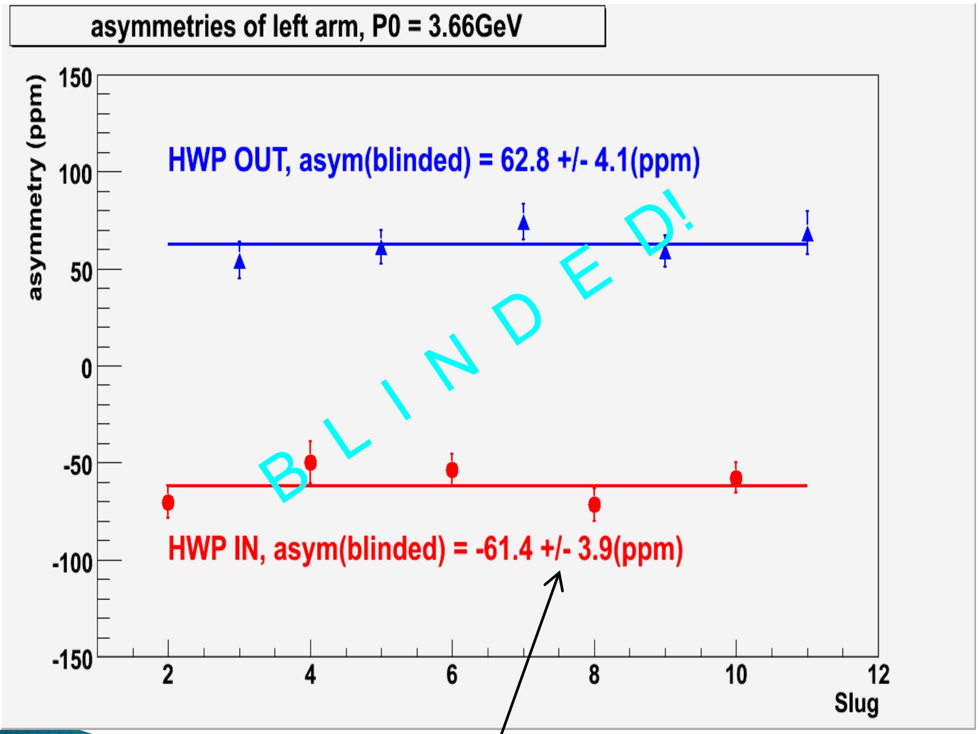
**1% (+ -) 0.2% correction on Asymmetry**

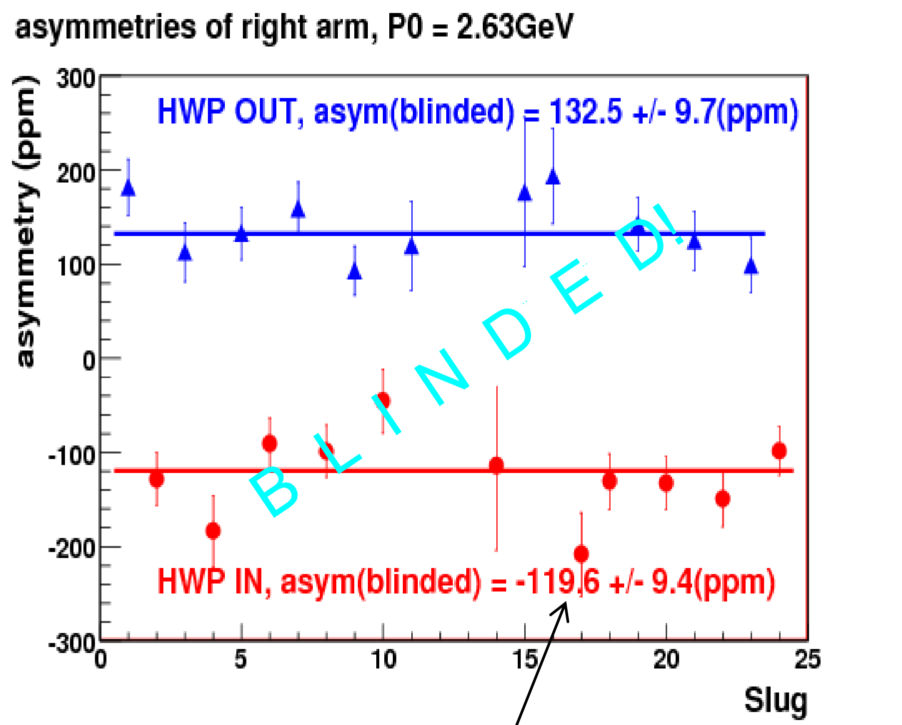


## 5. Parity DAQ data analysis (Blinded raw asymmetry)

- Arbitrary shift (blinding factor) on measured asymmetry to avoid analysis bias
- To do list before unblinding: Pedestal subtraction, BCM calibration, charge asymmetry analysis, selection of clean cut, regression and dithering correction, etc

Online Asymmetries, $Q^2$=1.1 $(GeV/C)^2$ | $Q^2$=1.9 $(GeV/C)^2$




will provide a ~3% relative uncertainty compared to the simulation 90 ppm

will provide a ~4% relative uncertainty compared to the simulation 161 ppm

# Section IV: Summary and Outlook

## Physics Goal

- Experiment will provide world highest-accuracy measurement on $(2C_{2u}-C_{2d})$, improving the uncertainty by a factor of four
- Constrain the hadronic effect, providing guide for PVDIS 12 GeV upgrade

## Data Analysis Progress

- Regular HRS DAQ data analysis is close to finalized
- Parity DAQ data analysis is ongoing
- Expected to release preliminary (unblined) asymmetry by the end of this summer